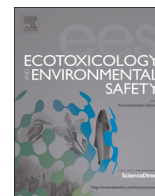




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Review

Arsenic contamination, consequences and remediation techniques: A review



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ABSTRACT

The exposure to low or high concentrations of arsenic (As), either due to the direct consumption of As contaminated drinking water, or indirectly through daily intake of As contaminated food may be fatal to the human health. Arsenic contamination in drinking water threatens more than 150 millions peoples all over the world. Around 110 millions of those peoples live in 10 countries in South and South-East Asia: Bangladesh, Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan, Taiwan and Vietnam. Therefore, treatment of As contaminated water and soil could be the only effective option to minimize the health hazard. Therefore, keeping in view the above facts, an attempt has been made in this paper to review As contamination, its effect on human health and various conventional and advance technologies which are being used for the removal of As from soil and water.

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1. Introduction

Recently, the environmental fate and behavior of arsenic (As) is receiving increased attention due to the arsenic (As) pollution in South-East Asia. Although As contamination in the environment has been reported worldwide (Sohel et al., 2009; Li et al., 2011), however, As pollution in groundwater has been a serious health threat to the human beings in South-East, South-West and North-East USA, inner Mongolia (China), South-West Taiwan coastal regions, Sonora (Mexico), Pamplonian Plain (Argentina), West Bengal (India), Northern Chile, and Bangladesh (Argos et al., 2010). The World Health Organization (WHO) deemed the As in Bangladeshi groundwater to be “the largest mass poisoning of a population in history” (Argos et al., 2010).

Arsenic is ubiquitous in the environment and highly toxic to all forms of the life. It is a crystalline “metalloid”, a natural element with features intermediate between metals and non-metals, occurs naturally as an element, ranks as the 20th most occurring trace element in the earth's crust, 14th in seawater, and 12th in the human body (Mandal and Suzuki, 2002). Arsenic exists mainly in four oxidation states – arsenate (As^{V}), arsenite (As^{III}), arsenic (As^{0}), and arsine ($\text{As}^{-\text{III}}$) and its solubility depends on the pH and ionic environment. Among them, the As^{V} being the most stable form (Sharma and Sohn, 2009; Zhao et al., 2010; Gupta et al., 2011). As^{V} is thermodynamically stable state in aerobic water, while As^{III} is predominant in reduced redox environment. Arsenic can be present in the environment in various chemical forms such as monomethylarsonic acid [MMA; $\text{CH}_3\text{AsO}(\text{OH})_2$], dimethylarsinic acid [DMA; $(\text{CH}_3)_2\text{AsOOH}$], trimethylarsine oxide [TMAO; $(\text{CH}_3)_3\text{AsO}$], arsenobetaine [AsB; $(\text{CH}_3)_3\text{As}+\text{CH}_2\text{COOH}$], arsenocholine [AsC], arsenosugars [AsS], arsenolipids etc. (Tangahu et al., 2011). In general, inorganic arsenicals are more toxic than organic ones (Meharg and Hartley-Whitaker, 2002). As^{III} is usually more toxic than As^{V} (Abedin et al., 2002a, 2002b; Schat et al., 2002), and dimethylarsinous acid (DMAAIII) and monomethylarsonous acid (MMAAIII) are more toxic than their parent compounds (Petrick et al., 2000; Mass et al., 2001). Methylated As compounds, such as MMA, DMA and TMAO are found sometimes as a minor component in the soil (Huang and Matzner, 2006), but can reach high concentrations (Abedin et al., 2002a, 2002b). Both MMA and DMA (also known as cacodylic acid) have been widely used as pesticides and herbicides, the DMA also as a cotton defoliant. Arsenobetaine, the dominant As species in marine animals, was found to be present in an acidic fen soil with unclear origin (Huang and Matzner, 2006). Arsenolipid, a lipid-soluble As compound, mainly found in the marine organism, and its concentration may reach up to 16 mg As/kg fish oil (Sele et al., 2012). Recent findings

suggested the following order in terms of acute As toxicity: MMA (III) > As^{III} > As^{V} > DMA(V) > MMA(V), where the MMA(III) metabolite is the most toxic compound and some researchers considered it to be the central As mode of action (EFSA, 2009; Kile et al., 2011; Wen et al., 2011). In this review, we have summarized As contamination and its remediation techniques in water and soil.

2. Sources of arsenic in the environment

The primary source of As in the environment (hydrosphere, pedosphere, biosphere and atmosphere) is the release of As from As-enriched minerals. The sources of As includes both natural i.e. through dissolution of As compounds adsorbed onto pyrite ores into the water by geochemical factors and anthropogenic i.e. through use of insecticides, herbicides and phosphate fertilizers, semi-conductor industries, mining and smelting, industrial processes, coal combustion, timber preservatives etc. (Mondal et al., 2006; Bundschuh et al., 2011). A survey of occurrence of As in groundwater/drinking water, fresh waters, marine waters, soil and food stuffs is given below.

2.1. Groundwater/drinking water

According to the WHO guidelines, the recommended limit of arsenic in drinking water is 0.01 mg L^{-1} . However, the levels of As in unpolluted surface water and groundwater vary typically from $1\text{--}10 \mu\text{g L}^{-1}$. Groundwater concentrations of As is reported to be very large range from less than $0.5\text{--}5000 \mu\text{g L}^{-1}$ covering natural As contamination found in more than 70 countries (Ravenscroft et al., 2009). The As contamination in groundwater in different parts of the world is summarized in Table 1. Large areas of Bangladesh, West Bengal and other states of India and Vietnam rely on As contaminated groundwater for irrigation of staple crops such as rice (Nickson et al., 1998; Berg et al., 2001; Abedin et al., 2002a, 2002b). On applying the WHO provisional guideline for drinking water of $10 \mu\text{g L}^{-1}$ of As, a worldwide population of more than 100 millions people are at risk, and out of these more than 45 millions people mainly in developing countries from Asia are at risk of being exposed to more than $50 \mu\text{g L}^{-1}$ of As, which is the maximum concentration limit in drinking water in most of the countries in Asia (Ravenscroft et al., 2009). Contamination of drinking water is the main source of As for human being but for the population not exposed to elevated As in drinking water, consumption of food grown in As-contaminated soil or irrigated with As-contaminated water represents the main sources of As intake for humans, which causes a life-threatening problem for millions of

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